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# Oligosegmental Correction of Post-Traumatic Thoracolumbar Angular Kyphosis

Kao-Wha Chang, MD

Seventeen patients with rigid thoracolumbar angular kyphosis due to neglected fractures or dislocations were treated by a standardized single-stage monosegmental or bisegmental anterior discectomy and posterior closing extension wedge osteotomy. The two- or three-level reduction-fixation (RF) instrumentation was used posteriorly for correction and fixation. Choosing angled pedicle screws according to preoperative measurements, the method can always correct the kyphosis to the approximate sagittal curvature that is planned to create preoperatively. The average precorrection of thoracolumbar kyphosis was 39° and was restored to 1.2° for an average correction of 37.8° (range, 22°–56°) with subsequent average loss of 1.1° at final follow-up. Before operation, the complaints were slow progression of kyphotic deformities, fatigue, and pain. All these problems were solved by this procedure. Complications were minimal and mild. No neurologic complications occurred. Follow-up averaged 2.8 years. This method can correct rigid post-traumatic thoracolumbar angular kyphoses to normal geometric relationships as planned preoperatively without much negative effect in lumbar motion and any sacrifice of safety. [Key words: rigid thoracolumbar angular kyphosis, reduction-fixation instrumentation, angular pedicle screw]

Short-curved or angular kyphoses in general have different pathogeneses that occur either by destruction (fracture, inflammation, tumor, or laminectomy) or by localized malformation (congenital). The resulting angulation is associated with a local derangement of the relationship between nerve, bone, and ligamentous structures. Likewise, cord and root compression, deformity, and segmental instability represent the clinical correlates, which demand surgical intervention. The treatment of angular kyphotic deformities has always presented a challenge to orthopaedic surgery.

Moe et al[9] have clearly outlined indications and treatment protocol for the treatment of angular kyphosis. General principles consists of 1) decompression of the neural canal; 2) traction for correction of deformity if indicated; 3) strut grafting anteriorly; and 4) supplementary posterior fusion with long instrumentation. When the angular kyphosis is located at thoracolumbar spine, the posterior long instrumentation has negative effect in lumbar motion and sometimes the sagittal curvature created can not be approximate to the curvature that the surgeons plan to create. Patients without neurologic defects can develop mechanisms of compensation; for paraplegics, however, a stiff thoracolumbar or lumbar spine provokes rehabilitation problems.[5] Furthermore, iatrogenic neural damage could happen if the deformity is corrected by a posterior long instrumentation without adequate anterior decompression of the neural canal and release of the rigid kyphus.[9]

When surgically treating rigid thoracolumbar angular kyphosis, the goals are to achieve the followings:

1. Reconstruction of normal geometric relationships must be accomplished according to preoperative planning.
2. Reconstruction procedures shall be as few segments as possible to avoid damaging or sacrificing healthy neighboring segments (as to other methods such as Harrington, Luque, Cotrel-Dubousset)
3. Secure and rigid fusion of bones must be achieved.
4. Complications should be minor and mild.

This article reports the results of 17 cases of post-traumatic thoracolumbar angular kyphosis treated with one-stage dorso-ventro-dorsal correction-fixation procedures and two- or three-level reduction-fixation (RF)[2–4] instrumentation (Figure 1) to achieve the above-mentioned goals.

## Materials and Methods

The patients in this series were treated at 803 Army General Hospital, Taiwan, the Republic of China. To obtain a uniform group of patients for study, all these patients met the following criteria: 1) All patients with angular kyphosis from causes other than trauma (congenital, developmental, and infective nature) were excluded. 2) All patients who had received previous operation for kyphosis or the injuries were excluded. 3) The location of kyphosis was limited to thoracolumbar region (T12–L5). 4) The rigidity of kyphosis was confirmed by flexion–extension stress films. Radiographic documentation and evaluation consisted of standing anteroposterior and lateral views. The kyphosis was measured between the superior

From the Division of Orthopaedic Surgery, Department of Surgery, 803 Army General Hospital, Taiwan, Republic of China.
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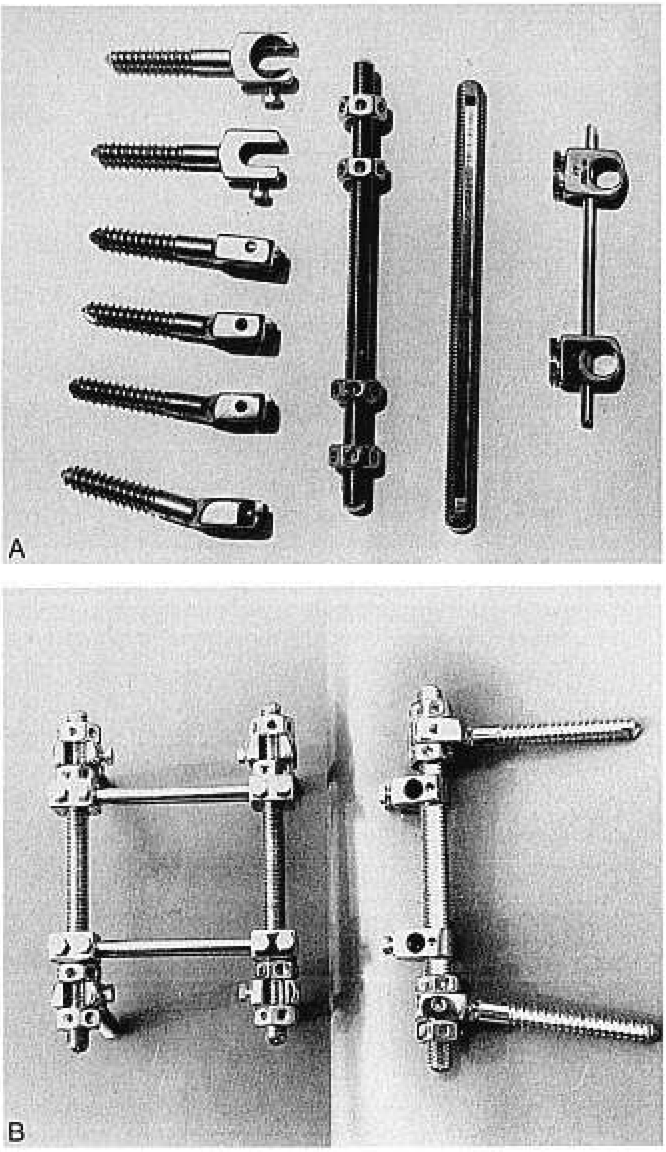


Figure 1. The reduction–fixation instrumentation system. **A,** The dissembled reduction–fixation system. The angled pedicle screws with set screws, the rod with traction nuts, and the transverse connector. The angled pedicle screw are U-shaped head screws and are offered in four angles: 0°, 5°, 10°, and 15°. This measurement is the degree of angle between the U-shaped screw head and the shank of the screws. **B,** The assembled reduction–fixation system. Note the lordotic tilt of the angled screws when the paired traction nuts are tightened to the U-shaped screw head. The angle of the lordotic tilt depends on which angled screw is chosen.

end-plate of the vertebra immediately above the wedged vertebra (for fractures) or the disruptive disc (for dislocations) and the inferior endplate of the vertebra immediately below the wedged vertebra or the disruptive disc. The fusions were evaluated with flexion–extension radiographs. Computed tomography and myelographic studies had been performed before operation to evaluate the topographic relationship of neural structures to vertebrae. The pertinent radiographs had been duplicated for each patient and were available at the time of review for all patients in the series. 5) The documentation of the patient's neurologic status by evaluation of muscle strength as recommended by Eismont et al[7] had been recorded in a prospective fashion at the time when the patient was seen in my hospital, during hospitalization, and at long-term follow-up. 6) All patients had a minimum of 2 years of follow-up.

Seventeen patients met these criteria. There were 14 men and 3 women, with an age range of 19–54, with a mean age of 41 years. The length of follow-up averaged 2.8 years (range, 2–4 years). The level of kyphosis was the 12th thoracic in 5, the first lumbar in 8, the second lumbar in 3, and the third lumbar in 1. The mean interval between injury and surgery was 4.5 years (range, 3–10 years). All patients felt progression of the deformities and all presented with low-back pain that was progressive in nature and a feeling of constant fatigue that became worse as the day went on. In this series, there were 11 patients with intact neurologic function, 6 patients with neurologic deficits—Class A, three patients, Class B, two patients and Class C, one patient. All patients underwent a single-stage monosegmental or bisegmental anterior discectomy and posterior closing extension wedge osteotomy. The two- or three-level RF instrumentation was used posteriorly for correction and fixation. Monosegmental correction-fixation procedures were used for cases of neglected dislocations. Bisegmental correction-fixation procedures were used for cases of neglected fractures. Spinal cord monitoring or the wake-up test has not been used in these cases. The excised discs were examined histologically by a pathologist. Patients were allowed to ambulate early postoperatively and were fitted with a plastic thoracolumbar orthosis which they wore from 3 to 6 months. All patients received prophylactic antibiotics for 48 hours.

**Surgical Technique and Planning.** The first procedure consisted of posterior osteotomy at the lamina of the wedged vertebra or at the facets of the level of disruptive disc and setting-up the RF system without tightening. The insertion of angled pedicle screws should be as parallel to the endplates as possible. For choosing angled pedicle screws of appropriate angulation, the thoracic kyphosis was used as a reference and the lumbar lordosis was created equal to or slightly larger than this measurement. In general, for the angular kyphosis at T12 and L1 levels, the angled screws of 0° angulation were used to create a straight thoracolumbar junction. For fractures below L1 (L2–L5), screws of 5°, 10°, or 15° angulation were used to create lumbar lordosis, gradually increased the degree of angulation at each level caudally.

The second procedure consisted of temporarily closing the wound, repositioning the patient in lateral decubitus position with left side up, and exposing the ventral portion of the kyphosis through transthoracic retroperitoneal or retroperitoneal approach, and anterior discectomies including the contracted anterior longitudinal ligament through the discs above and below the wedged vertebra back to the posterior longitudinal ligament.

The third procedure began with opening the dorsal wound. The deformity could be corrected to the lordosis, which was created by tightening the traction nuts to the U-shaped screw heads of the angled pedicle screws that had been implanted posteriorly at the beginning of the operation. Bone grafts taken from the left iliac crest were cut into measured pieces and inserted into the disc space after correction. The excised rib and iliac bone grafts were used for posterolateral fusion of the instrumented segments. Additional transpedicular compression

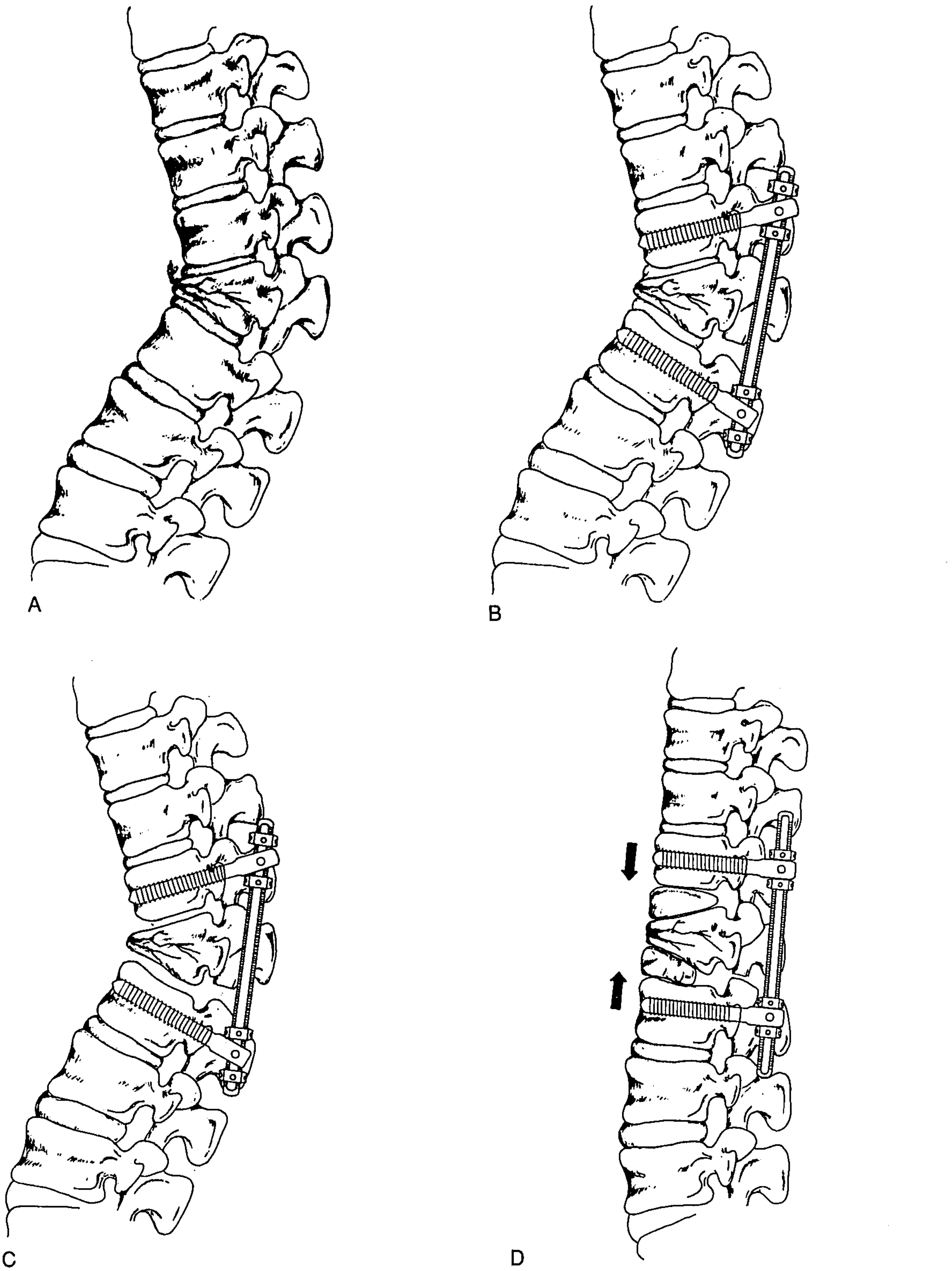


Figure 2. Procedures of bisegmental correction of rigid thoracolumbar angular kyphosis. **A,** The rigid thoracolumbar angular kyphosis. **B,** The first procedure includes V-shaped osteotomy of the lamina of the wedged vertebra and implantation of appropriate angled pedicle screws to the vertebrae above and below the wedged vertebra. The rods are locked in the U-shaped screw heads of the angled screws but the traction nuts are not tightened. **C,** The second procedure is anterior bisegmental discectomy, including the contracted anterior longitudinal ligament. **D,** The third procedure begins with tightening the traction nuts to correct the kyphosis to the preset angulation. Anterior and posterior iliac bone grafts, compressive spondylodesis, and locking the RF system are performed sequentially.

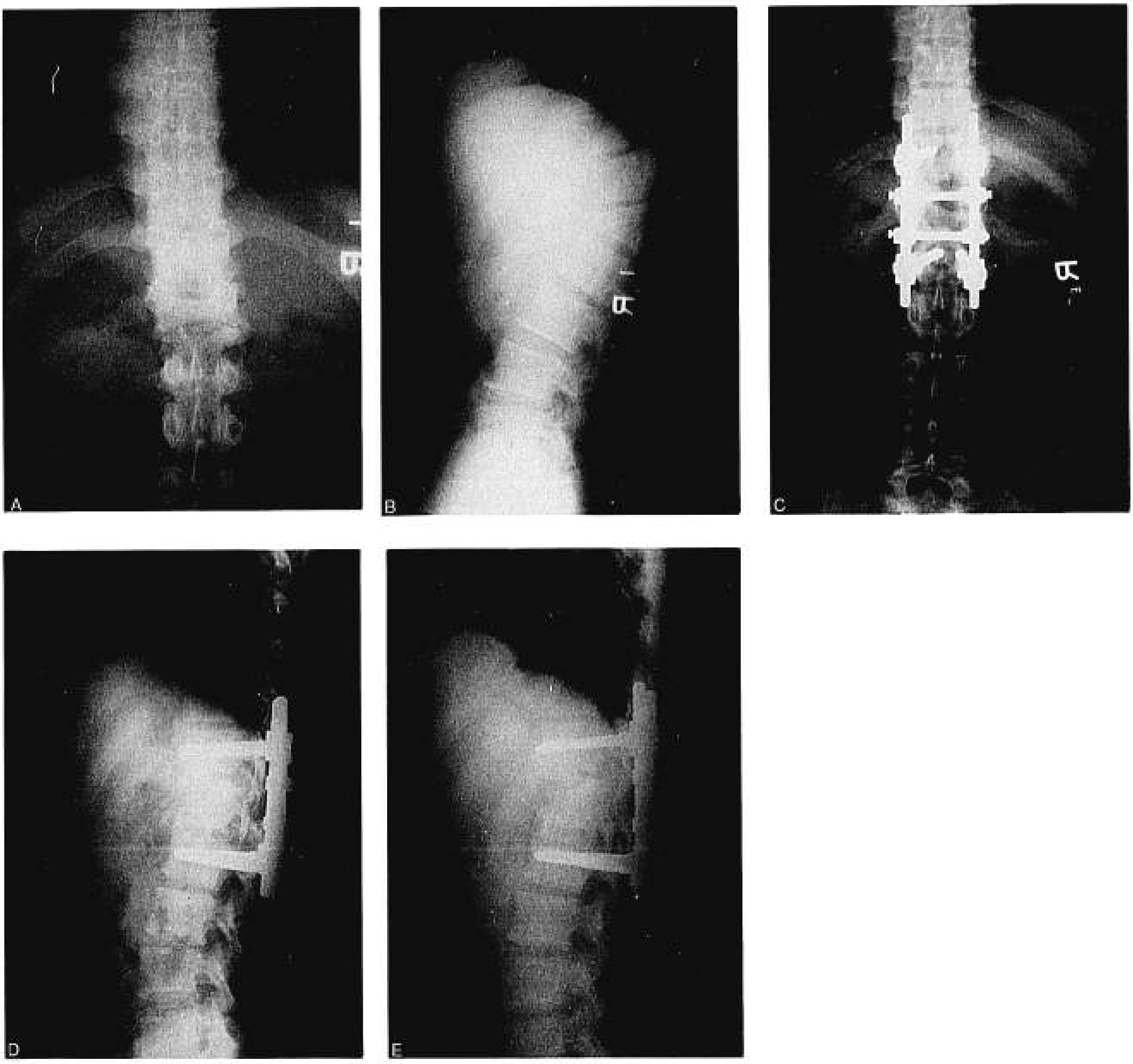

Figure 3. A 35-year-old man had incurred a 12th vertebral fracture 4 years before he presented to our clinic with a rigid thoracolumbar angular kyphosis (Case 7). **A** and **B**, Preoperative anteroposterior and lateral radiographs showed the already healed wedged vertebral body and angular kyphosis of 52°. **C** and **D**, One month postoperative anteroposterior and lateral films showed bisegmental discectomy, iliac bone grafts, and three-level RF instrumentation. The kyphosis was corrected to a near-straight thoracolumbar junction (7°). In this case, 0° angled pedicle screws were chosen to try to create a straight thoracolumbar junction. **E**, One-year postoperative film demonstrated solid fusion. The thoracolumbar junction remained straight (8°) with little loss of correction.

was applied through RF to allow compressive spondylodesis of all columns, and finally the RF system were totally locked in place by breaking the head of the set screws. The wounds were closed over suction drains (Figures 2–4).

## ■ Results

The clinical data and surgical results of these 17 patients are listed in Table 1. There were 5 monosegmental and 12 bisegmental correction-fixation procedures. The average total operative time was 4.5 hours, with a range of 3.5–6.5 hours. The average blood loss was 837 cc, with a range of 500–1,370 cc. The average duration of stay in hospital postoperatively was 14 days. All patients with neglected fractures were found to have disruption of posterior ligamentous complex and already healed wedged vertebral bodies. The histologic studies of the excised disc specimens showed degenerative changes.

The average kyphosis before correction was 39°, with a range of 28–58°. After correction, the kyphosis measured on average 1.2°, with a range of 10° to −14°. This represented a change of 37.8°, with a range of 22–56° (Table 1). Bone union of the osteotomy or

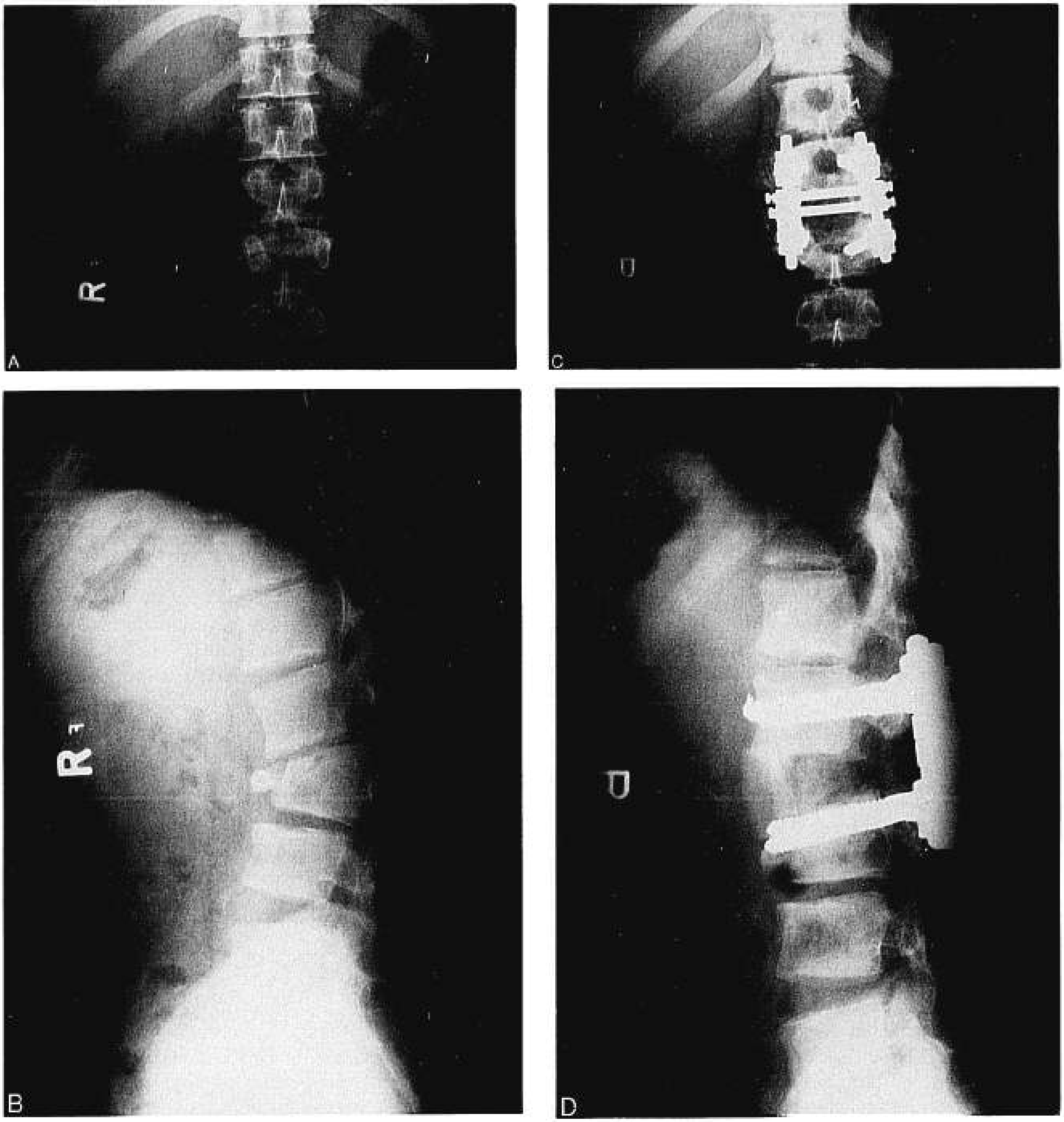


Figure 4. A rigid lumbar angular kyphosis caused by neglected L1–L2 dislocation (Case 10). **A** and **B**, Preoperative anteroposterior and lateral radiographs showed an angular kyphosis of 33°. **C** and **D**, Postoperative anteroposterior and lateral radiographs showed monosegmental discectomy, compressive spondylodesis with iliac bone grafts and two-level RF instrumentation. The kyphosis was corrected to 7° lordosis. In this case, 5° angled pedicle screws were chosen to try to create a regional lordosis of 10°.

discectomy was obtained at 1-year follow-up in all cases. After solid fusion, the kyphosis had a mean value of 2.3°. Pain relief was obtained in all cases.

There was no deterioration of neural function (Table 2). All patients with intact neurologic function before operation remained so after operation. Two of the patients with neural deficit improved one class. No lethal complications, no implant failure, and no wound infections occurred. One patient had significant postoperative ileus requiring prolonged D-tube drainage. Two patients developed urinary tract infections in the immediate postoperative period, but these were resolved promptly with antibiotics.

**Table 1. Results of Surgical Correction in Seventeen Patients**

| Case | Age | Level of Kyphosis | Kyphosis (degree) Initial | Soon after Correction | Final Follow-up |
|---|---|---|---|---|---|
| 1 | 19 | T12 | 32 | 0 | 2 |
| 2 | 44 | T12 | 42 | 10 | 7 |
| 3 | 53 | L1 | 41 | 6 | 5 |
| 4 | 32 | L2 | 28 | −3 | −2 |
| 5 | 40 | L1 | 40 | −5 | −3 |
| 6 | 41 | L1 | 58 | 2 | 4 |
| 7 | 35 | T12 | 52 | 7 | 8 |
| 8 | 41 | L1 | 33 | 9 | 9 |
| 9 | 52 | L1 | 44 | 6 | 8 |
| 10 | 26 | L2 | 33 | −7 | −6 |
| 11 | 54 | T12 | 43 | 9 | 10 |
| 12 | 51 | L1 | 42 | 3 | 4 |
| 13 | 50 | L2 | 45 | −4 | −2 |
| 14 | 40 | L1 | 41 | −4 | −3 |
| 15 | 43 | T12 | 29 | 7 | 10 |
| 16 | 47 | L3 | 30 | −14 | −10 |
| 17 | 30 | L1 | 32 | −2 | −2 |
| Mean | 41 | | 39 | 1.2 | 2.3 |

## ■ Discussion

Stability of the spine is dependent on two distinct bone columns. The construction crane is an ideal model for this two-column concept. The vertebral bodies and discs correspond to the boom of the crane and are designed to withstand compression forces. The cables, or guy wires, represent the posterior elements and are subjected to tensile forces in the erect posture. Weakening or destruction of either component results in collapse into kyphosis. The thoracolumbar spine is not truly axially loaded, because the center of gravity lies anterior to the anterior aspect of the thoracic spine. In most thoracolumbar fractures, if both bone columns fail at the same level, an angulated or short-curved kyphosis rather than a long-curved kyphosis will develop. The short-curved kyphosis moves the center of gravity farther anteriorly, thus increasing deforming forces. The discs (mainly the upper one) immediately adjacent to the injured vertebra degenerate under such deforming forces. The fractured vertebral body can heal and consolidate with sufficient strength to withstand the deforming force, but the posterior ligamentous injury which is not always apparent early after the accident is difficult to heal strongly enough to stop progression of the kyphosis. Because of a lack of preoperative data, the author cannot document objectively the progression of the kyphosis, but all patients felt progression of the kyphotic deformity after the accident. During operation all patients were found to have healed wedged vertebral bodies and disrupted posterior spinal structures. The histologic studies of the excised disc specimens confirmed the degenerative change. In cases with thoracolumbar dislocations of the spine, the posterior ligaments and intervertebral discs are at least partly destroyed. These injuries usually result in chronic instability, and progression of the kyphotic deformities. Spontaneous fusions are extremely rare.

Reconstruction of normal geometric relationships has to be achieved when treating the angular kyphosis. Posterior spinal fusion alone is in most cases not sufficient for the angular kyphosis.[1,10] Posterior fusion in the presence of existing kyphosis and bony deformity places bone grafts under tension in the presence of a large bending moment. The inevitable result is pseudoarthrosis. Posterior correction is difficult in the presence of contracted and healed anterior soft tissue. Finally, the spinal cord cannot be adequately decompressed through the posterior approach because the offending compression is located anteriorly. If surgery is restricted to an anterior approach, correction of a deformity is often hindered by posterior structures. After fractures and dislocations, there may be ankylosis or bony obstacles with the danger of cord impingement. In addition, the bending moment that remains after anterior correction may be one of the major causes in 50% of the failures that

**Table 2. Preoperative and Postoperative Functional Neurologic Levels**

| Eismont et al Functional Neurologic Level: Preoperative | | Postoperative A | B | C | D | Total |
|---|---|---|---|---|---|---|
| A | 3 | 3 | 0 | 0 | 0 | 3 |
| B | 2 | 0 | 1 | 1 | 0 | 2 |
| C | 1 | 0 | 0 | 0 | 1 | 1 |
| D | 11 | 0 | 0 | 0 | 11 | 11 |
| Total | 17 | 3 | 1 | 1 | 12 | 17 |

occur when ventral surgery is performed exclusively.[8] Donk et al[6] reported 8 of 16 cases treated between 1980 and 1984 by ventral surgery alone, suffered loss of correction of more than 10%.

Because anterior and posterior spinal structures are involved, the strategy for the correction of the rigid angular kyphosis is a dorso-ventro-dorsal procedure in order to achieve lasting correction and secure fusion. After thoroughly circumferential release, the angular kyphosis can always be easily corrected to the curvature planned preoperatively and permanently fixed by the RF instrumentation. The discrepancy between the planned and postoperative curvature was due to the inaccurate placement of angled pedicle screws, which should be parallel to the end-plates of the instrumented vertebrae. Because operative intervention and spinal instrumentation were limited to the levels immediately above and below the wedged vertebra or the disruptive discs, reconstruction of normal geometric relationships could be accomplished without damaging or sacrificing healthy neighboring segments. Thus, little iatrogenic loss of lumbar mobility is ensured. This is important especially for the rehabilitation of paraplegic patients, where independence depends on the mobility of the lumbar spine.[5]

The neurologic recovery after correction is not within the scope of this report. In this series, two of the four patients with partial neurologic deficit (Classes B and C) improved one class of neurologic function. The author must emphasize that there was no deterioration of neurologic function due to correction. Iatrogenic neural damage might happen by correction with the posterior long instrumentation (such as Harrington, Lugue) because the displacement between the instrumented vertebral segments and the neural structures within the short-segment of the angular kyphosis are opposite each other and might cause compression of neural structures. This method can minimize the incidence of iatrogenic neural damage, because the displacement between the neural structures and instrumented vertebral segments is synchronous by only correction-instrumentation of the involved segments of the angular kyphosis.

With the aid of three-column lordotic compression by the RF system, this method also allows a stable, load-bearing compression spondylodesis to promote rapid fusion. All patients in this study had solid fusion at 1-year follow-up.

## ■ Conclusion

In this series of 17 cases with post-traumatic rigid thoracolumbar angular kyphosis, the sagittal alignment and normal geometric relationships were approximately recreated according to preoperative planning. All reconstructive procedures were limited to the involved segments of the short-curved kyphus (monosegmental or bisegmental) to minimize the negative effect in lumbar motion and the incidence of iatrogenic neural damage. All patients obtained sound union of fusion at 1-year follow-up. The complications were minor. This method achieved the goals of surgical treatment of rigid thoracolumbar angular kyphosis.

The best treatment of angular kyphosis is its prevention. For this reason, in spinal instabilities in which the dorsal and ventral columns are affected, the author strongly advocates surgical treatment before decompensation occurs.

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*Address reprint requests to*

Kao-Wha Chang MD
*No. 115-1*
*Alley 322, Section 1*
*Chung-Shan Road*
*Taiping, Taichung Hsein*
*Taiwan, Republic of China*